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Hybridization of Vitis Rotundifolia

Inheritance of Anatomical Stem Characteristics

C. F. WILLIAMS, *Asst.*
Division of Horticulture

NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION
Conducted Jointly by The State Department of Agriculture and
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HYBRIDIZATION OF VITIS ROTUNDIFOLIA

INHERITANCE OF ANATOMICAL STEM CHARACTERS

By C. F. Williams, *Assistant*
Division of Horticulture

In plant breeding, especially of horticultural crops, little or no attention has been paid to anatomical characters. Only those of weight, size, color, etc., and such physiological characters as sugar, starch, and protein content have been studied. In fact, rarely is a cross effected in which the anatomy of the parents differs sufficiently to make possible any comparison. However, in hybridizing *Vitis rotundifolia* with other species of Vitis, individuals with considerable difference in anatomy have been successfully crossed and the hybrid vines obtained are of interest from this viewpoint. It is possible to examine the hybrid stems not only for such superficial characters as smoothness, color, hardness, size, etc., but also for the fundamental anatomical structure which is the basis of these, and therefore the critical point of attack for a genetical study.

Vitis rotundifolia, the southern muscadine grape, differs considerably from other species of the genus Vitis, especially in certain of the stem characters. Gray (1) has divided the genus Vitis into two sub-genera. Under one, Muscadinia (Planch.) he places *V. rotundifolia* and under the other, Euvitis (Planch.), he includes all other grapes. Small (2) has reserved the genus Vitis for the bunch grapes proper and makes a separate genus for the muscadine grape, namely Muscadinia (Small). This will give some idea of the extent to which *V. rotundifolia* species differ from the other species of Vitis. Only those differences that affect the material under discussion will be considered here.

The hybrid vines on which the following report is based are some grown in determining the limits of hybridization of *Vitis rotundifolia* with other species of Vitis. The particular crosses used are as follows:

TABLE 1. PARENTAGE OF HYBRIDS

Year Made	No. of Vines	Description of Cross
1917	26	V. vinifera (var. Malaga) x V. rotundifolia
1916	7	V. bourquiniana (var. Herbemont) x V. rotundifolia
1912-16-18	26	Hybrid (Labrusca x Aestivalis x Vinifera var. Winchell) x V. rotundifolia.
1917	1	Hybrid (Winchell x V. rotundifolia) x V. rotundifolia

This does not mean that these are the only crosses of *V. rotundifolia* that have been secured. Other hybrids obtained have not been used

because of insufficient growth in some cases, and death of the vines in others.

These vines have already been described as to their external characters by Detjen (3). This paper is limited to the gross anatomy of the mature one year canes of the parent vines and their F_1 generation hybrids. Material was collected during the early winter of 1921-22, and again in the winter of 1922-23. In order to have a uniform basis of comparison, only mature one year canes were used. Transverse, radial, and tangential sections were cut 25-30 microns thick, from the middle of the internode with a table microtome. Combination stains of safranin with Delafield's hematoxylin or with light green were used. Table 2 lists the different species and varieties of Vitis examined during this investigation.

TABLE 2. SPECIES OF VITIS EXAMINED

SPECIES	VARIETY	NO. OF VINES
Rotundifolia	Pure species and varieties	12
Vinifera	Malaga	3
Bourquinana	Herbemont	2
Labrusca	Concord	2
Labrusca	Pure species	3
Cinerea	Pure species	1
Arizonica	Pure species	1
Californica	Pure species	1
Aestivalis	Pure species	5
Aestivalis	Norton	1
Munsoniana	Pure species	1
Champini	Pure species	1
Bicolor	Pure species	1
Simpsoni	Pure species	1
Doaniana	Pure species	1
Hybrid	(Labrusca x Aestivalis x Vinifera) Winchell	2
Hybrid	(var. Winchell x V. rotundifolia)	26
Hybrid	(V. vinifera x V. rotundifolia)	26
Hybrid	(V. bourquiniana x V. rotundifolia)	4
Hybrid	[Hybrid (Winchell x V. rotundifolia) x V. rotundifolia.]	1

VITIS ROTUNDIFOLIA

Bark. The bark of *V. rotundifolia* is greenish-grey in color, rather smooth, and has numerous lenticels. It is very persistent, never shedding on the young wood, and on the very old wood falling off in small corky flakes. The stems of the young vines resemble those of maple saplings much more than they do the vines of the Euvitis group.

Wood. The wood is very hard and compact, the specific gravity being about 1.26 with the result that the stems will sink in water. The hardness of the wood is especially noticeable in pruning as the stems are much more difficult to cut than any Euvitis species.

Pith. The diameter of the pith column is very small, particularly as compared with other species of Vitis, but widens out at the node

(Fig. 1), at which there is no diaphragm. The pith is light green in color and so dense that Munson (4) in describing it says, "in place of pith a dense, dark green, cellular, nonfibrous wood." The cells are uniform in size in the node and internode, very thick walled and pitted. Starch is stored throughout the pith column.

Xylem. In *V. rotundifolia* the xylem forms a greater part of the stem than any other species (Fig. 3). Moreover, it is distinguished from Euvitis species by the character of the wood, which is composed of numerous tracheæ or vessels embedded in a mass of wood fibers (Fig. 4), both of which are smaller in diameter than those of other species, except *V. munsoniana.* These fibers, which are almost round, are septate and have extremely thick walls and a very small lumen. They are lignified to a greater degree than Euvitis species as is seen in the difficulty in cutting the stems, in the staining reaction, and in the thick walls.

The vessels are of considerable diameter (Fig. 4), although the smallest to be found in Vitis species, and very long, due to many of the cross walls having been dissolved away. The pitting consists of elongated horizontal slits closed by thin membranes, as is common among vines. These pits are of two sizes depending on whether the vessel is in contact with wood fibers or with other vessels. Where the tracheæ adjoin wood fibers, the pits are fairly small horizontal slits arranged in vertical rows. If one vessel is in contact with another, the slits are very long, extending almost the width of the vessel. Tyloses occur in the vessels, the occluding cells being thin walled, parenchymatous, and not pitted.

Phloem. The arrangement of the elements of the phloem (hard and soft bast) in the Muscadinia species differs from that in the Euvitis species. Figure 4 is a photomicrograph of a cross-section of a bundle showing the phloem and part of the xylem and wood rays. Here in *V. rotundifolia* the phloem as seen in transverse section is triangular in outline with the hard bast more or less radially disposed on the sides of the soft bast. That is, the portion of the cambium differentiating hard bast remains about the same, while the increased circumference due to growth is adjusted by an increase in the amount of cambium forming soft bast. This widening of the phloem accompanying the growth of the stem results in a triangular-shaped mass of this tissue. The hard bast is composed of thick walled septate wood fibers. The cells of the soft bast, which are small and thin walled, are somewhat irregularly disposed.

External to the phloem there is a small round bundle of sclerenchyma fibers forming the apex of the triangle mentioned above. These fibers are extremely long, nearly round, very thick walled with small lumen, and septate.

Rays. The rays of all Vitis species are of the compound wood ray type common in vines. These are several cells wide and extend longitudinally through the internode and are full of starch (Fig. 4). Those of *V. rotundifolia* are not as broad as the ones of the Euvitis group. The most significant characteristic as contrasting with the other Vitis species is that portion of the ray extending between the phloem bundles. In *V. rotundifolia* the ray in this region expands by cell multiplication to fill the widening gap between the phloem as the stem increases in circumference (Fig. 4). This is clearly evident in the arrangement of the cells which here are formed in tangential rows, contrasting with the radial rows of the ray proper.

Cortex. The cortex in *V. rotundifolia* is in sharp contrast with that of the bunch grape type (Fig. 4), and the seat of this difference lies in the phellogen or cork cambium. In the Muscadinia species the phellogen is formed immediately under the epidermis, and produces internally the phelloderm of varying thickness. This is composed of parenchymatous cells in irregular longitudinal rows. *V. rotundifolia* is further characterized by the presence of numerous lenticels which penetrate the cortex for a considerable depth opposite the ends of the rays (Fig. 4).

VITIS VINIFERA

Bark. The bark of *V. vinifera* is red-brown to greyish-brown in color on the young wood. It is finely striated and sheds in long fibrous plates.

Wood. The wood is very soft and porous. It is light in weight (specific gravity less than 1.0), quite brittle, and more or less oblong in cross section.

Pith. The diameter of the pith column in comparison with that of the stem is much greater than in the case of *V. rotundifolia.* Figure 5 of *V. vinifera,* which is of the same magnification as Figure 3 of *V. rotundifolia,* shows the proportion of the tissues in section. The pith cells of *V. vinifera,* as may be seen in a comparison of these two photomicrographs, are much larger and thinner walled. The pith is dry and light brown in color and contains little or no starch. At the node, there is a distinct diaphragm (Fig. 2) composed of thick walled lignified cells with pitted walls.

Xylem. The elements of the xylem (vessels and wood fibers) are larger in diameter than are those of *V. rotundifolia.* This is best seen by contrasting Figure 5 with Figure 3. The wood fibers are more angular in section and not as thick walled, nor as lignified, and are in more distinct radial rows (Fig. 6). There are more vessels and they are larger in this species than in *V. rotundifolia,* but the sculpturing is similar. Tyloses in the vessels are common in this species. One occluded vessel may be seen in cross section at the lower right in Figure 6 and several in Figure 5.

Phloem. The arrangement of the phloem in *V. vinifera* is typical for all Euvitis species. Figure 6 is of the phloem portion of a bundle of *V. vinifera* and should be contrasted with Figure 4 of *V. rotundifolia* which is of the same magnification. In transverse section it is almost square in outline and is composed of alternating tangential layers of hard and soft bast. Thus in contrast with the Muscadinia type, the cambium forms first a layer of soft bast and then a layer of hard bast, each several cells deep, and repeating this differentiation until there may be as many as six or seven pairs of layers. The cells are arranged in radial rows and are of larger size than those of *V. rotundifolia.* The hard bast cells are more angular in outline and thinner walled than in that species, and the soft bast cells are much larger. External to the phloem of the bundle is a semicircular column of sclerenchyma fibers. They contrast with those of *V. rotundifolia* in being arranged in larger bundles which are semicircular, in being larger in diameter and very angular, and thinner walled.

Rays. The rays of *V. vinifera* (Fig. 6) are compound wood rays as in other Vitis species, though considerably wider than those of *V. rotundifolia.* In contrast with these latter, they extend between the phloem bundles without widening through cell multiplication. Thus, the growth of the stem causes the cells to become pulled tangentially and distorted, especially at the ends of the rays.

Cortex. As the cortex of Euvitis species is shed, the appearance in the cross section of the mature one year wood is quite different from that of the Muscadinia species (Fig. 6). The phellogen forms immediately external to the phloem and inside of the sclerenchyma bundles. This layer of cork cells cuts off the water supply of the tissues outside of it, causing them to dry out and fall off. As the stem increases in circumference, there is no multiplication of cells as in *V. rotundifolia* so that the cells are much distorted and torn. Thus the cells in this region are very irregular and compacted. There are no lenticels present in this type of stem, the open ends of the rays serving this purpose and often at the time that the bark is shed, simulating them in appearance.

V. VINIFERA X V. ROTUNDIFOLIA HYBRIDS

Bark. Most of the hybrids of this cross have a light greyish-brown bark which is obscurely striated and has few lenticels, and sheds in small flakes rather than in fibrous plates as in *V. vinifera.* The appearance of the stems is rather smoother than that of either parent due to the smaller number of lenticels and a more obscure striation. The number of lenticels varies inversely with the extent to which the bark is shed, some vines having a more or less persistent bark with many lenticels, and others having a loose bark and fewer lenticels and more striations.

Wood. The wood is intermediate between the two parents and is

usually somewhat brittle. It is not as hard as *V. rotundifolia* but seldom as soft as *V. vinifera*. The specific gravity in all but two cases was greater than 1.0, and hence fresh-cut wood sinks in water. In cross section the stem is more or less elliptical rather than oblong as the *V. vinifera* parent, but not often as round as in *V. rotundifolia*.

Pith. The diameter of the pith column of the hybrids is a little less than the average of the two parents and it varies in color from light green to light brown. The size of the pith cells at the internode is about the same as in *V. rotundifolia,* but those at the node vary in size with the extent to which there is an expression of a diaphragm. In a small percentage of the hybrids (two of the twenty-six examined) there was a distinct diaphragm at the node visible to the naked eye. In the others there was a tendency for the cells at the node to be compacted in a vertical direction. In order to arrive at some conclusion as to the extent of this compaction the number of cells in a given area in an average region of the longitudinal section was counted. The results are given below:

TABLE 3

VINE	NUMBER OF CELLS AT		RATIO
	NODE	INTERNODE	
Vinifera	227	89	2.54 : 1
Rotundifolia	135	136	1.00 : 1
Hybrid with diaphragm	138	40	3.45 : 1
Hybrid without diaphragm	139	88	1.58 : 1

The above table would indicate that the cells of the internode resemble the *V. rotundifolia* parent, and that the cells at the node are more or less influenced by the *V. vinifera* parent. It was also observed that the increase in the number of cells at the node was due to a lessening of their vertical height with little change in their horizontal diameter.

Xylem. The character of the xylem is intermediate between that of the parents. The hybrids vary, however, through all the range, one in fact going beyond *V. vinifera* in size of cells and number of vessels. The fibers are larger than in *V. rotundifolia* but not as angular as in *V. vinifera.* The tracheæ also are larger than those of *V. rotundifolia* and the sculpturing is that typical of Vitis species. Some of the variation in the size and number of vessels of the hybrids is shown in Figures 7-10, and 13-38.

Phloem. In hybrids the arrangement of the elements of the phloem as seen in the transverse section covers the ranges of both parents. There is, however, a greater resemblance to the staminate parent in the majority of cases. In most of the vines there is a radial row of hard bast of greater or less extent on the sides of the phloem bundle (Figs. 7 and 8). In addition to this, there is also a tendency for tangential

layers of hard bast to appear in the bundle itself, either starting from one side or both sides and not reaching all the way across, or extending all the way across the bundle (Fig. 9). In only two instances did the bundle resemble that of Euvitis species, one of which is shown in Figure 10. It is remarkable that the pattern of the phloem bundle as seen in cross section varies in the same stem to a very considerable extent, showing a lack of fixation of this character in a given stem (see Figs. 13-38). Some of the vines, however, are quite uniform in their pattern. Inasmuch as the cambium determines the formation of hard or soft bast under unknown influences, in cases where the pattern in which these elements are laid down varies in the same stem, it would seem that the cambium of the stem must vary in its constitution.

The size of the cells of the hard and soft bast is intermediate, as is the thickness of their walls, and their shape. The sclerenchyma bundle is more *V. rotundifolia* in character, though usually of larger size than this parent.

Figures 11 to 38, inclusive, are camera lucida diagrams of the same magnification of *V. vinifera, V. rotundifolia,* and their hybrids. The hard bast of the phloem (also the bundle of sclerenchyma fibers) is shown stippled. Figures 13 to 38 show different degrees of intermediacy of character in the hybrids. Figures 13 and 15 show two adjacent bundles each with contrasting arrangements of the hard and soft bast. Such cases are quite common among the hybrids. Figures 14, 20, 25, and 33 show a progression in the range between the two types of arrangement. Only in Fgures 33 and 35 has the *V. vinifera* character approached dominance. Figure 34 shows the elements of the hard bast scattered indiscriminately through the soft bast.

Rays. The character of the intervascular ray varies with the character of the phloem. If the bundle is triangular as in *V. rotundifolia,* the ray immediately widens out by cell multiplication as in this parent (Fig. 7), but if the phloem bundle is broad and square the ray extends out without increasing in width as in *V. vinifera* (Fig. 10). In some cases the ray extends part of the depth of the bundle before widening out, showing most exactly the intermediate character (Figs. 8 and 9).

Cortex. The cortex in the hybrids shows less fixation of a definite character than any other part of the stem, varying from a close resemblance to the staminate parent to a similarity to the pistillate parent. In most cases, the cortex is very much like that of the *V. rotundifolia* species. Only the two that have the V. vinifera-like phloem have a cortex resembling that parent. In many of the vines there is a great variation in the same stem, one side being quite different from the other, or having patches of V. vinifera-like cortex with large, loose, torn cells outside of a cortex otherwise resembling *V. rotundifolia* (Fig. 8 and 9). In the examples illustrated in Figures 7 and 8 the type of cortex shown is not typical for the entire section of the stem

but only for a small number of bundles, more striking because of their irregular occurrence.

The indeterminate location of the phellogen seems to be the cause of this variation. It appears in the photomicrographs as a whitish layer due to the stain washing out of the suberized tissues. Its position varies not only in different vines but usually in the same vine (Fig. 7). In some cases, it is just under the epidermis as in *V. rotundifolia*. In other cases, it is inside of the sclerenchyma bundle as in the other parent (Fig. 10). Quite often there is an isolated layer of suberized tissue surrounding only one bundle of sclerenchyma fibers (Fig. 29). Frequently all three of these positions for the phellogen are found in the same stem, and in some instances at the same point in the stem. Usually the cortex inside the cork cambium resembles the *V. rotundifolia* parent, and that outside the *V. vinifera* parent (Fig. 9). Lenticels were present only where the phellogen is immediately under the epidermis. This scattered distribution of the cork cambium is responsible for the exfoliation of the bark in small flakes.

In Figures 11 to 38 the phellogen is shown in solid black. Figures 11 and 12 represent the parents, and Figures 13 to 38 the hybrids, which show all degrees of the cork cambium character expressed in the parents. Bundles diagrammed are more or less typical for the particular stem, but do not by any means represent the condition of each bundle of the stem. In Figure 13, for example, the phellogen occurred outside of only a few bundles at this particular location which is used to illustrate the arrangement of hard and soft bast in the phloem. Such cases as shown in Figures 19, 24, 37, and similar ones, usually occurred only in small patches of the circumference of the transverse section. In Figure 31 isolated suberized cells are scattered through the cortex.

VITIS BOURQUINIANA, Variety Herbemont

The stem of *V. bourquiniana* so closely resembles that of *V. vinifera* that a detailed description of it is unnecessary in this place. If any difference exists in the characters in question it is perhaps that the cells have thinner walls (Fig. 45).

V. BOURQUINIANA X V. ROTUNDIFOLIA HYBRIDS

It was possible to examine only four of the hybrids of this cross. The expression of the intermediate character is similar to that in the *V. vinifera* hybrids. There is, however, no example of the phloem bundle resembling that of the Euvitis parent and the resemblance was predominantly toward the other parent. In view of the small number of vines studied, this was hardly significant.

Diagrams of these hybrids are shown in Figures 39 to 44, inclusive, Figures 39 and 40 being from one vine, and Figures 43 and 44 from

another single vine. In these cases the bundles were not adjacent but came from different parts of the same transverse section. The pair in Figures 39 and 40 show well, not only the tendency to form alternate layers of hard and soft bast, but also (Fig. 40) the squaring up of the bundle due to the intervascular ray not widening out by cell multiplication. Figure 43 shows the varying amount of phellogen in the same stem. Figure 42 is of interest because of the small amount of hard bast fibers present.

VARIETY WINCHELL

(Hybrid of V. labrusca, V. æstivalis, V. vinifera)

While it has not been possible, as yet, to pick out distinctive specific characters of the stem on the basis on which this study is made for the different species of Vitis, the anatomical characters of Winchell resemble most closely of the three parents, those of *V. aestivalis,* and the differences noted in the following description vary from the *V. vinifera* species in that direction.

Bark. The bark is reddish-brown in color, striated and shedding in long fibrous plates.

Wood. The wood is soft and brittle and quite porous. It is light in weight and almost round in cross-section.

Pith. The pith column is very large in diameter and larger in proportion to the diameter of the stem than *V. vinifera* (Fig. 46). In this, it resembles the *V. labrusca* parent. The pith is dry and loose, light-brown in color, and composed of large, thin-walled cells. There is a thick diaphragm at the node composed of compact lignified pith cells with thick walls having simple pits.

Xylem. The xylem of this variety is quite like that of *V. vinifera,* but the bundle is not as deep in proportion to the stem diameter on account of the large pith. The cells are a little smaller and not as thick walled. (Fig. 46.)

Phloem. The phloem is in the typical arrangement for Euvitis species. The cells are more uniform in size and smaller than *V. vinifera.* The fibers of the sclerenchyma bundle differ very little from those of *V. vinifera* (Fig. 47).

Cortex. The cortex in this species differs but little from that of *V. vinifera* as above described.

V. VAR. WINCHELL X V. ROTUNDIFOLIA HYBRIDS

Bark. Most of the hybrids of this cross have a rather smooth, reddish-brown bark, darker in color than the *V. vinifera* hybrids. On these the bark sheds either in long fibrous plates or in smaller flakes. Others of the cross have a persistent bark which is lighter in color and more of a greyish-brown, with many lenticels.

Wood. The wood is soft and very brittle, snapping off easily at the node and only a little less easily at the internode. The section of the stem is almost round in outline.

Pith. The diameter of the pith varies widely between that of the two parents, which are extremes in either direction for size of all the vines examined. In color, some have a light brown pith and others light green as in *V. rotundifolia.* In this latter case, the pith is usually continuous without a distinct diaphragm at the node. The others have a more or less complete diaphragm. Of the twenty-six examined, eleven have definite diaphragms at the node visible without the use of the lens. In those with continuous pith the cells at the node were compacted and lignified to a varying extent.

Xylem. The xylem is more nearly like that of the variety Winchell, especially in the size and shape of cells, although the walls are thicker than those of this variety.

Phloem. In these hybrids there is a great variation in the pattern of the phloem as examined in the transverse section. In eleven of the twenty-six the hard and soft bast are disposed in a manner similar to that in the Euvitis species. In the others, there is more or less similarity to the staminate parent, although there is a greater tendency for the hard bast to form tangential layers across the bundle regardless of the shape of the bundle than in the case of *V. vinifera* hybrids. The bundle of sclerenchyma fibers varies with the type of phloem bundle. The square Winchell-like bundle is accompanied by a bundle of sclerenchyma fibers similar to the same species.

The camera lucida diagrams shown in Figures 48-75 inclusive, represent bundles from each of the hybrids of this cross; Figures 55 and 56 being from the same vine, and Figures 60 and 61 from another single vine. The range of the intermediate character of the hard bast is shown by Figures 49, 51, 53, 56, 60 and 66. This is also well shown in the one vine represented by Figures 55 and 56, or in Figure 62. The vines represented by Figures 55 and 58 are interesting because of the scarcity of hard bast present in the phloem.

Rays. The rays show the same correlation with the shape of the phloem tissue as in the case of the *V. vinifera* hybrids, that is, the intervascular ray expands by cell multiplication when the phloem bundle is sufficiently triangular in shape to cause a tangential strain (Fig. 76).

Cortex. The cortex of these hybrids is extremely irregular. The predominant character is the excessive amount of cork cambium at scattered points in the transverse section (Fig. 77). This lack of definite character for the phellogen is greater than in the case of the *V. vinifera* hybrids. In some instances, the entire thickness of the cortex seems to be completely of suberized tissue (Figs. 76 and 78).

The diagrams in Figures 48-75 illustrate the various amounts and ar-

rangements of the cork cambium. The quantity varies from that shown in Figure 51 to that of Figure 58, and its position in relation to other tissues varies greatly in depth as shown in Figures 52 and 63. In Figures 68-74 inclusive, the drying out of the cells outside of the suberized layer was so complete that this portion of the cortex fell off either before or after cutting the section. In each of these cases, the phellogen was located inside of the sclerenchyma bundles.

HYBRIDS VAR. WINCHELL—V. ROTUNDIFOLIA HYBRID X V. ROTUNDIFOLIA

There is only one vine of this cross and it is so small and weak that it would be unwise to draw any conclusions from it. It is, however, predominantly *V. rotundifolia* in character, which, inasmuch as this is the staminate parent, would indicate its hybrid character. The stem and bark resemble this parent and the pith is small, light green and continuous. The transverse section of the stem shows strongly the *V. rotundifolia* parentage in the pattern of the phloem bundle, the proportion of elements and the presence of lenticels. At one point of this section there is an excessive amount of dry cortex outside of the phelloderm resembling the hybrids of the F1 generation.

DISCUSSION

It has been possible in the hybridization of Vitis species to cross individuals that have considerable difference in the anatomy of the stem structure. These characters are inherited by the hybrid offspring so that there is an opportunity to study the inheritance of characters that are of greater fundamental importance from a genetical viewpoint than such superficial ones as color, weight, size, etc. No doubt, some of these characters may be correlated with other external morphological ones, but the study of the inheritance of these essential structural characters should be of great value to an understanding of the principles of heredity.

The varying degree of expression of the blended intermediate character in the offspring would probably be best explained by a multiple factor hypothesis. The small number of individuals available and the fact that only the F_1 generation has been studied would make it impossible to draw any definite conclusions.

It is very significant, however, that the intermediate condition of the anatomical stem characters varies in degree not only in the different hybrid vines, but also in the same individual. It is a striking fact that neighboring and even adjacent bundles in the same transverse section may resemble different parents. In such small stems, this condition cannot be explained as a response to external environmental factors. This condition approaches a chimera but differs from it in the lack of total dominance of expression of either parent. Actually there are different degrees of blending in the same individual. There

are here several interdependent characters. Changes affecting one of them therefore will to some extent influence the others. Where the degree of inheritance of the intermediate condition is uniform for each character of the individual, there is a stem that is fairly uniform in its composition. On the other hand, where the degree of inheritance of the different characters varies for the individual, the influence of the related characters results in a complex condition. It is necessary to consider this on the basis of the generative tissue of the cambium. It would appear that the cambium varies in its hereditary composition, a difficult thing to explain or believe.

It would probably be advisable if possible to determine the immediate causes influencing the formation of hard bast in the phloem, and the formation of phellogen. Knowing these influences, it might be possible to find a hereditary factor or factors which would control these characters.

In regard to the formation of phellogen, Douliot (5) finds that the cork in the stem may be superficial, pericylic or intermediate in origin. In the parents of the crosses described here, the Euvitis species have the cork cambium pericylic, and the Muscadinia species superficial. However, the lack of an intermediate condition for this character in the hybrids of the F_1 generation but rather a proliferation of suberized tissue would indicate the inheritance of a tendency to form cork cambium in both locations.

Priestley (6) has studied the formation of phellogen from the casual standpoint, finding that it is related to "1, the blocking of a parenchymatous surface usually by a deposit of suberin or cutin formed in the presence of air; 2, the accumulation of sap at the parenchymatous surface thus blocked; 3, the consequent development and activity of a phellogen amidst this parenchyma." This would hold true in the case of the parents of these hybrids. In Muscadinia species the sap can move outward in the stem to the epidermis where it is blocked and phellogen subsequently formed. In the Euvitis stem the cortical cells are destroyed during the expansion of the stem and air enters as deep as the endodermis and the cork cambium is formed here. In the hybrids where a combination of these conditions exist, it is difficult to explain phellogen formation as due to these causes, especially in those cases where there is a layer of isolated phellogen around a bundle of sclerenchyma fibers, or where there are two layers of phellogen. In other cases it would appear that the location of the cork cambium depended on the ability of the cortical cells to multiply and thus present a layer of parenchymous cells impervious to the air. Such an explanation practically removes the phellogen from direct inheritance by hereditary factors, the hereditary factors controlling only the cambium and the tissues formed by it, and the phellogen formation being controlled by air and moisture.

The significance of the different degree of intermediate inheritance

in the hybrids of *V. rotundifolia* with *V. vinifera* var. Malaga, and with Vitis hybrid var. Winchell has not been determined. The difference between *V. rotundifolia* and each of these is apparently about the same as far as actual characters are concerned. Whether the genetical difference is greater in case of var. Winchell crosses due possibly to its own hybrid nature, is still to be investigated. Unfortunately, individuals of crosses between *V. rotundifolia* and each of the species represented in the pedigree of Winchell cannot at this time be examined. A study of *V. labrusca* and *V. æstivalis* has given no additional information.

This study of the anatomy of the stems of Vitis species probably explains the difficulty of rooting Muscadine cuttings, and grafting *V. vinifera* on Muscadinia species roots. It may be possible to develop a hybrid root resistant to phylloxera and on which the *V. vinifera* may be easily grafted.

SUMMARY

The stems of the subgenera of Vitis, namely, Muscadinia and Euvitis, have distinctly different anatomical characters.

These characters may be summarized as follows:

Character	*Muscadinia*	*Euvitis*
Bark	persistent	shedding
Lenticels	present	absent
Pith	small, of thick-walled cells	large, of thin-walled cells
Diaphragm	absent at node	present at node
Wood fillers	small diameter, thick-walled	larger, thin-walled
Phloem section	triangular	square
Hard bast	outlines soft radially	in alternate layers with soft fibers
Sclerenchyma fibers	small bundle of round thick-walled fibers	large bundle of angular fibers
Rays in intervascular region	widen by cell increase	continue the same width
Phelloderm	present	absent
Phellogen	immediately under epidermis	just outside of phloem
Sp. gravity of fresh cut wood	greater than water	less than water

In crosses between the species of these subgenera, the hybrids inherit the anatomical characters as well as the morphological characters, and just as strikingly as the external characters usually studied.

These characters in the hybrids were intermediate resembling either parent with varying degree, but with possibly greater resemblance to the *V. rotundifolia* parent.

In the hybrids with var. Winchell there was less resemblance to the *V. rotundifolia* parent than in the *V. vinifera* hybrids.

The degree of the expression of the intermediate condition was about uniform in all the characters of any one vine. That is, a vine with

more resemblance to one parent in any character had more resemblance to that parent in the other characters.

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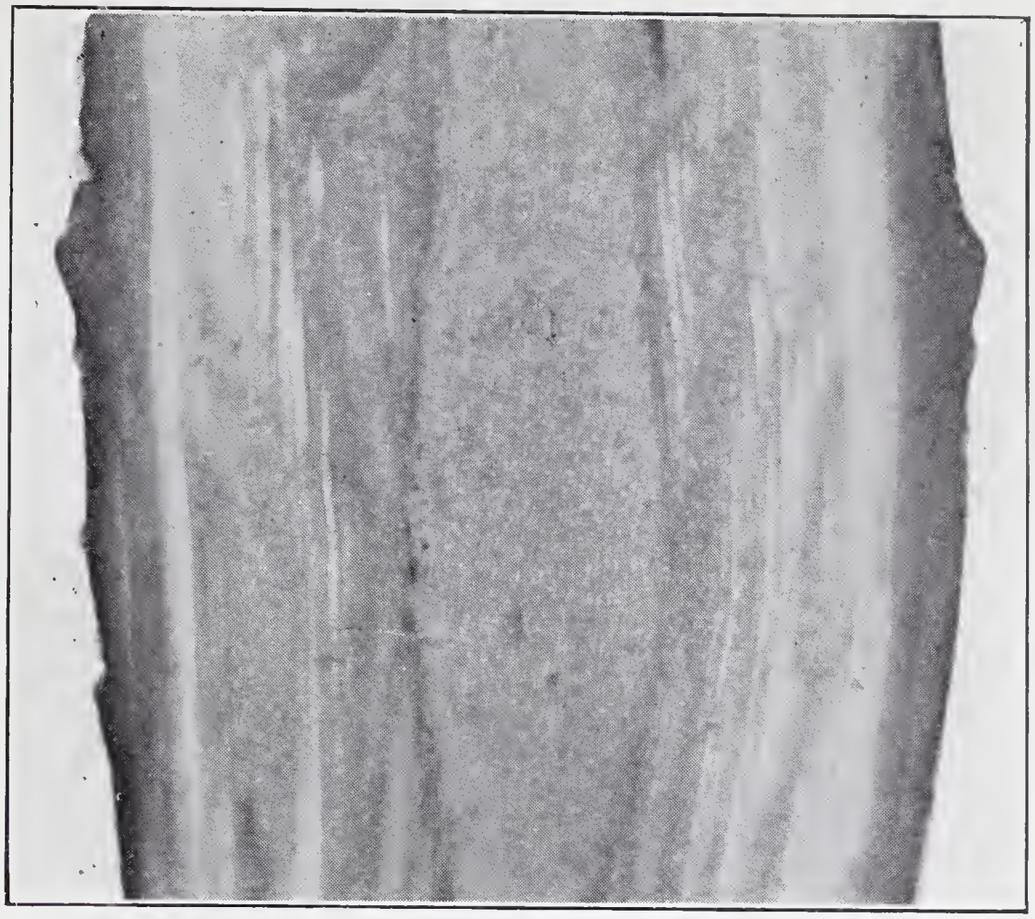

FIG. 1. VITIS ROTUNDIFOLIA, LONGITUDINAL SECTION THROUGH THE NODE

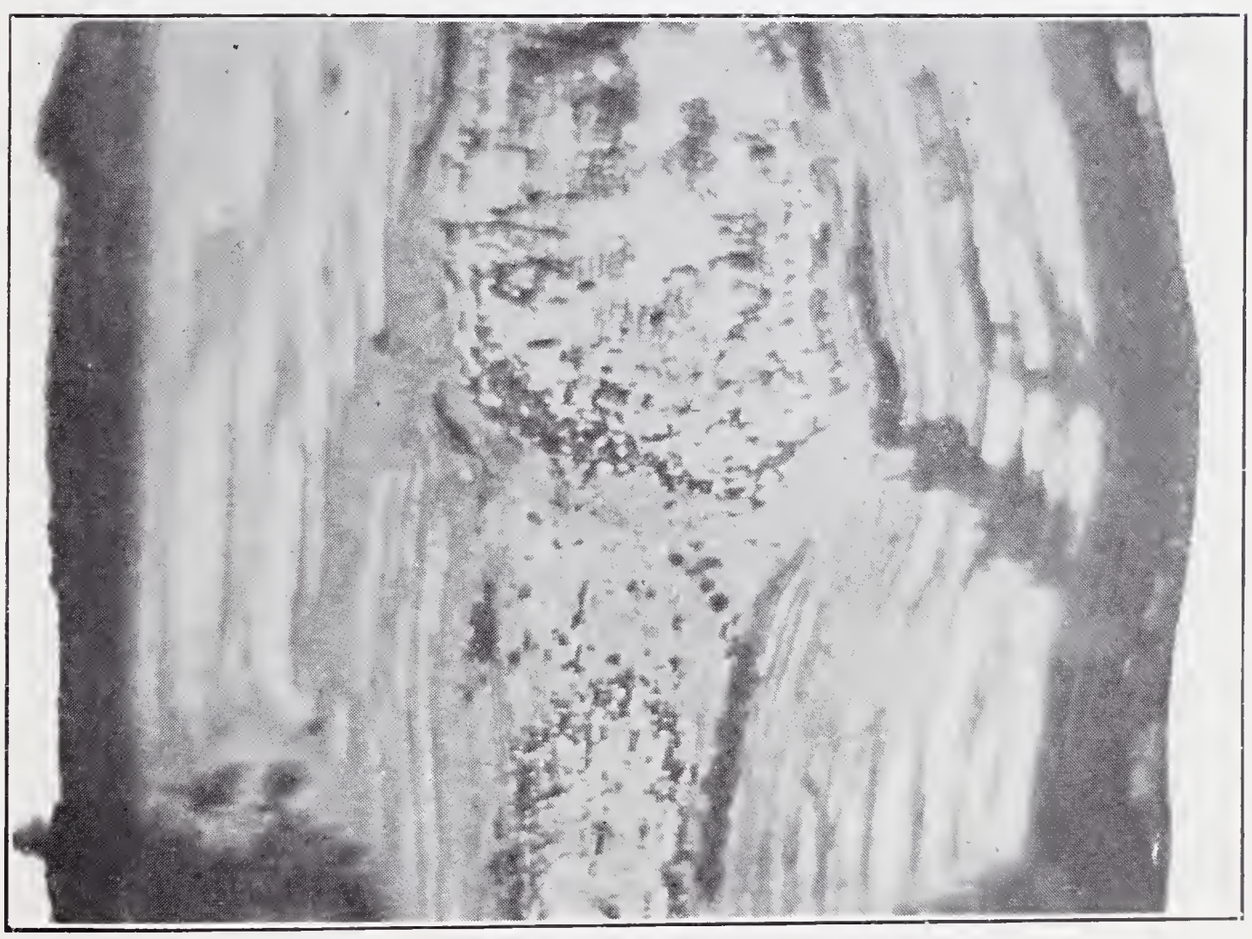

FIG. 2. VITIS VINIFERA, LONGITUDINAL SECTION THROUGH THE NODE.

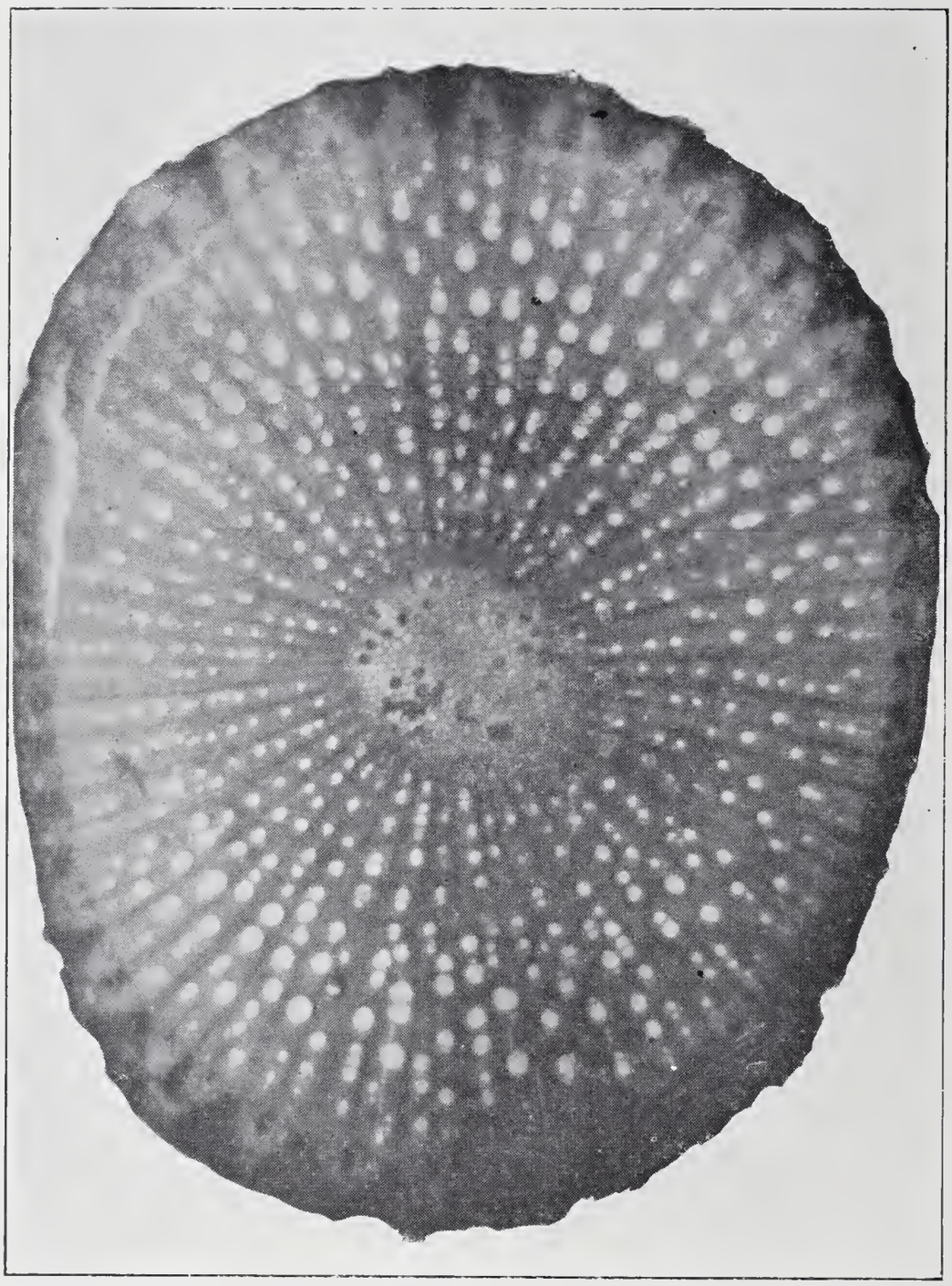

FIG. 3. VITIS ROTUNDIFOLIA, TRANSVERSE SECTION OF INTERNODE.

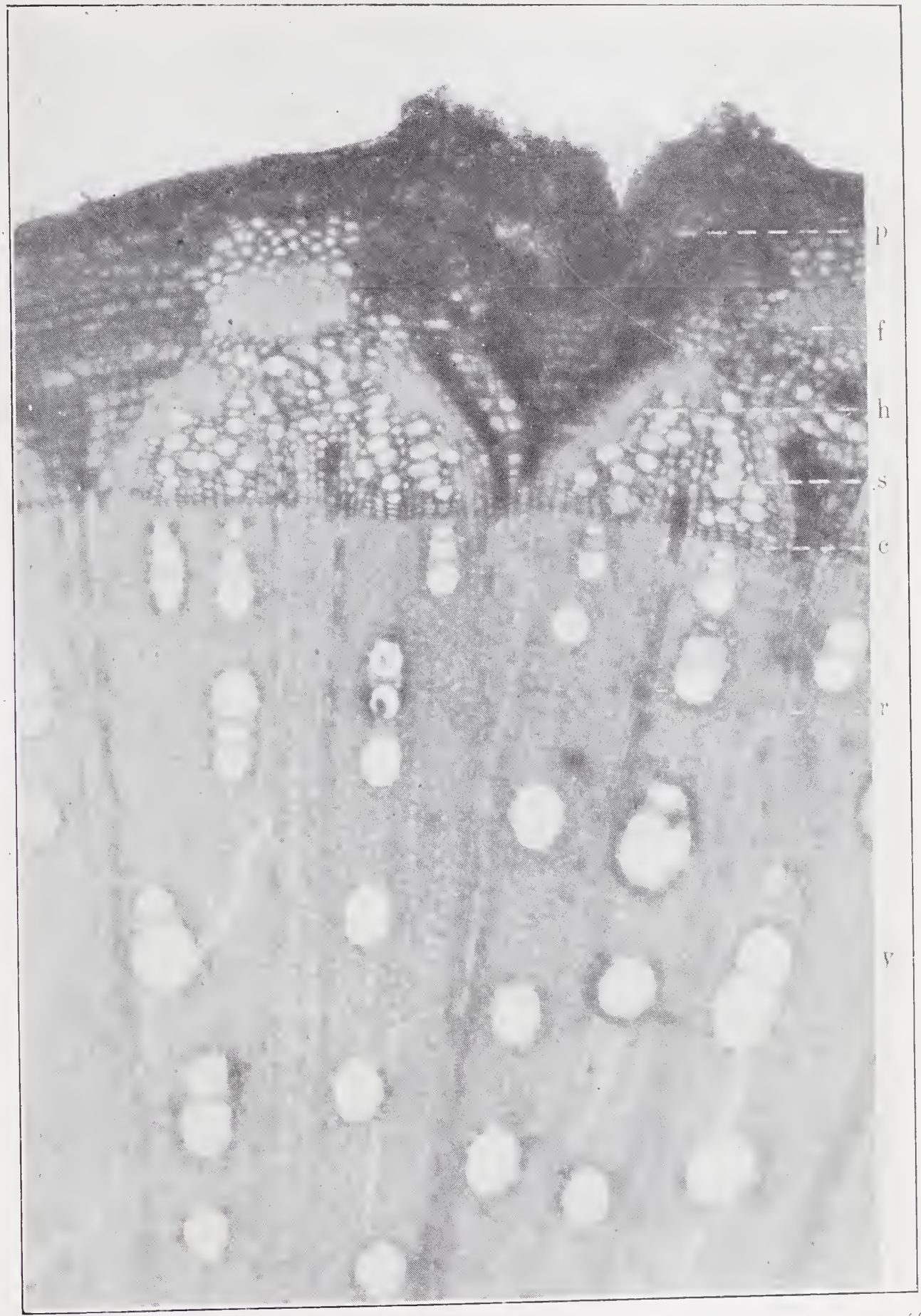

FIG. 4. VITIS ROTUNDIFOLIA, TRANSVERSE SECTION OF BUNDLE, (*p*) PHELLOGEN, (*f*) SCLERENCHYMA FIBERS, (*h*) HARD BAST, (*s*) SOFT BAST, (*c*) CAMBIUM, (*r*) RAY, (*v*) VESSELL.

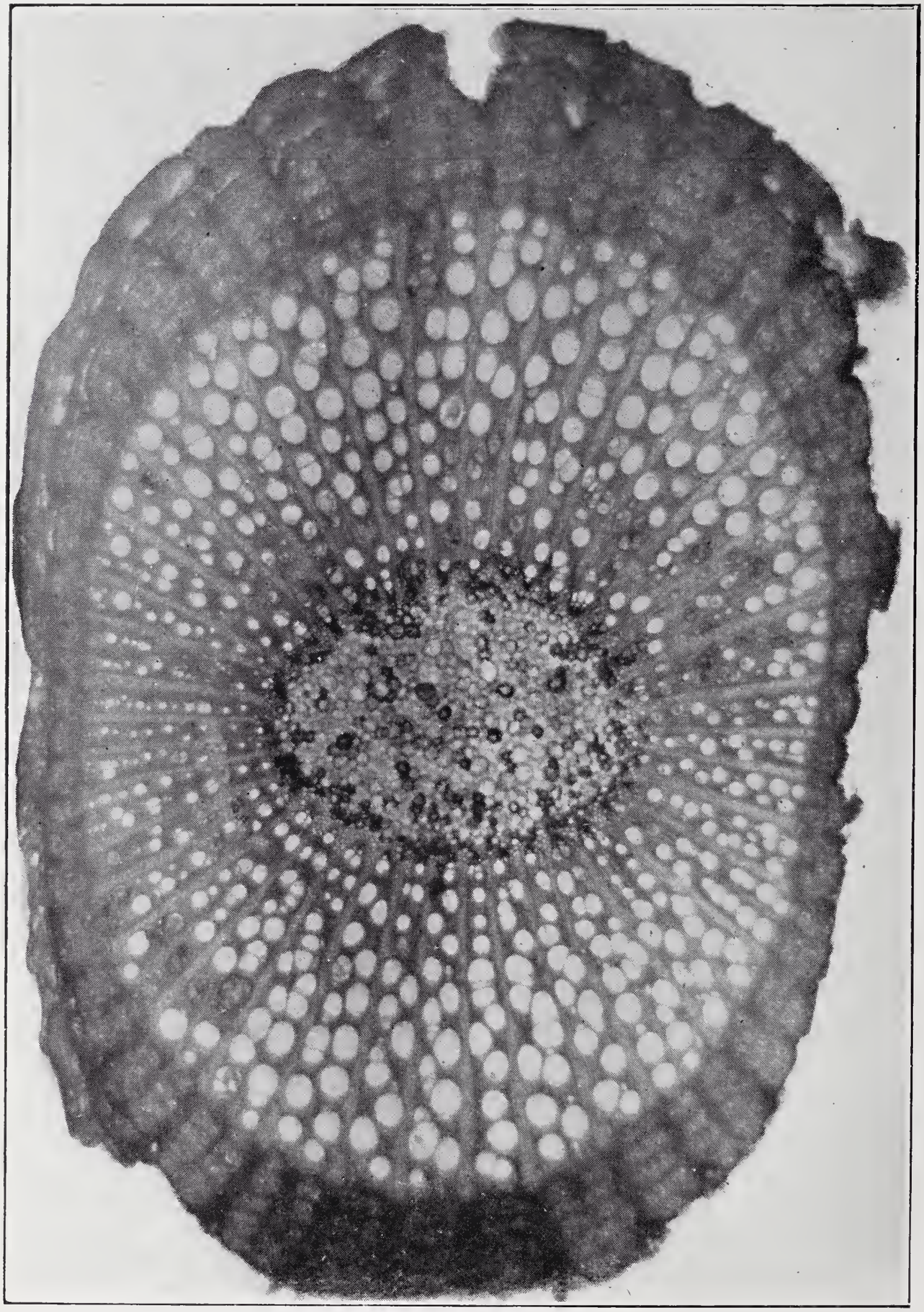

FIG. 5. VITIS VINIFERA, TRANSVERSE SECTION OF INTERNODE.

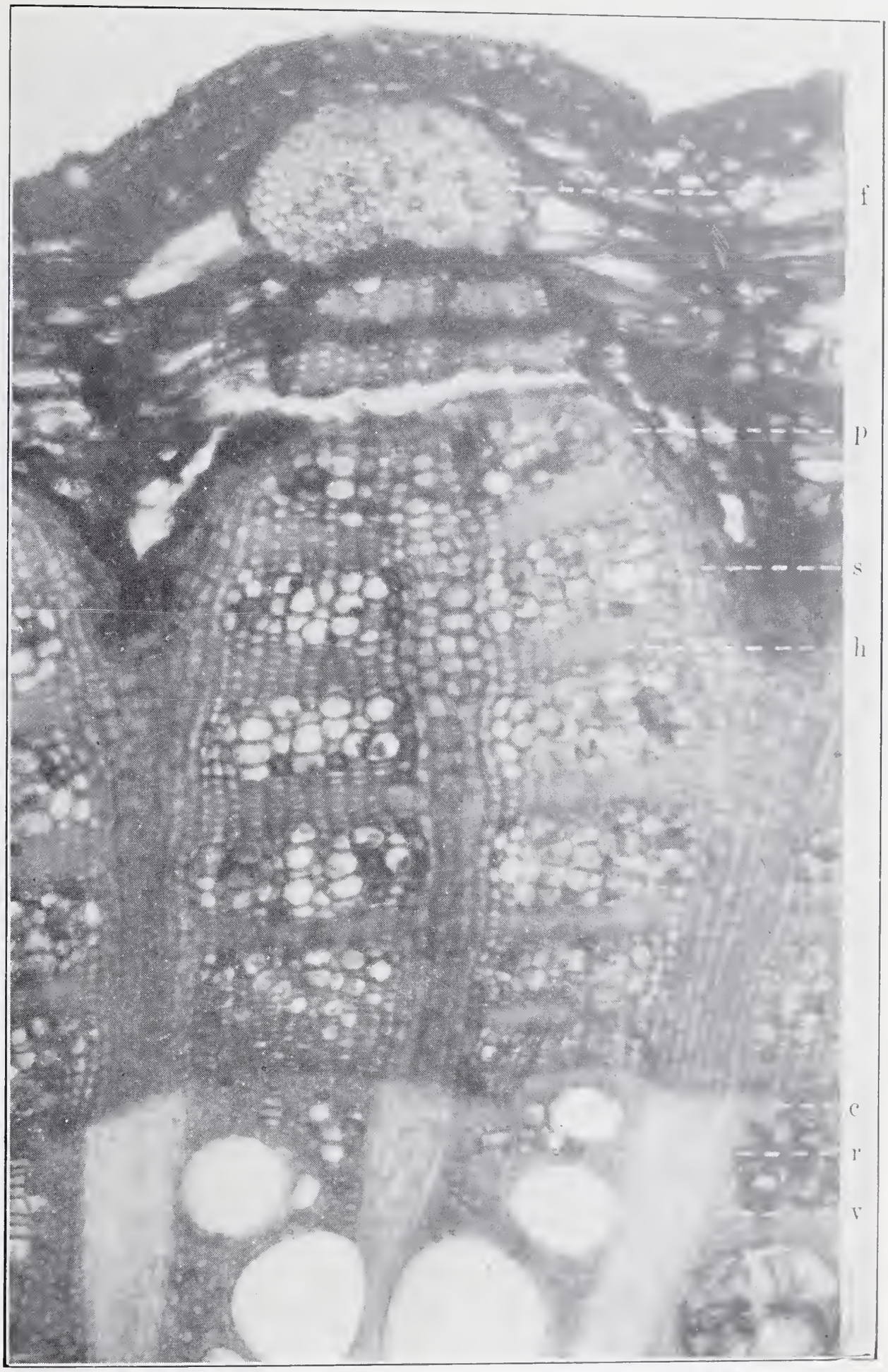

FIG. 6. VITIS VINIFERA, TRANSVERSE SECTION OF BUNDLE, (*p*) PHELLOGEN, (*f*) SCLERENCHYMA FIBERS, (*h*) HARD BAST, (*s*) SOFT BAST, (*c*) CAMBIUM, (*r*) RAY, (*v*) VESSEL.

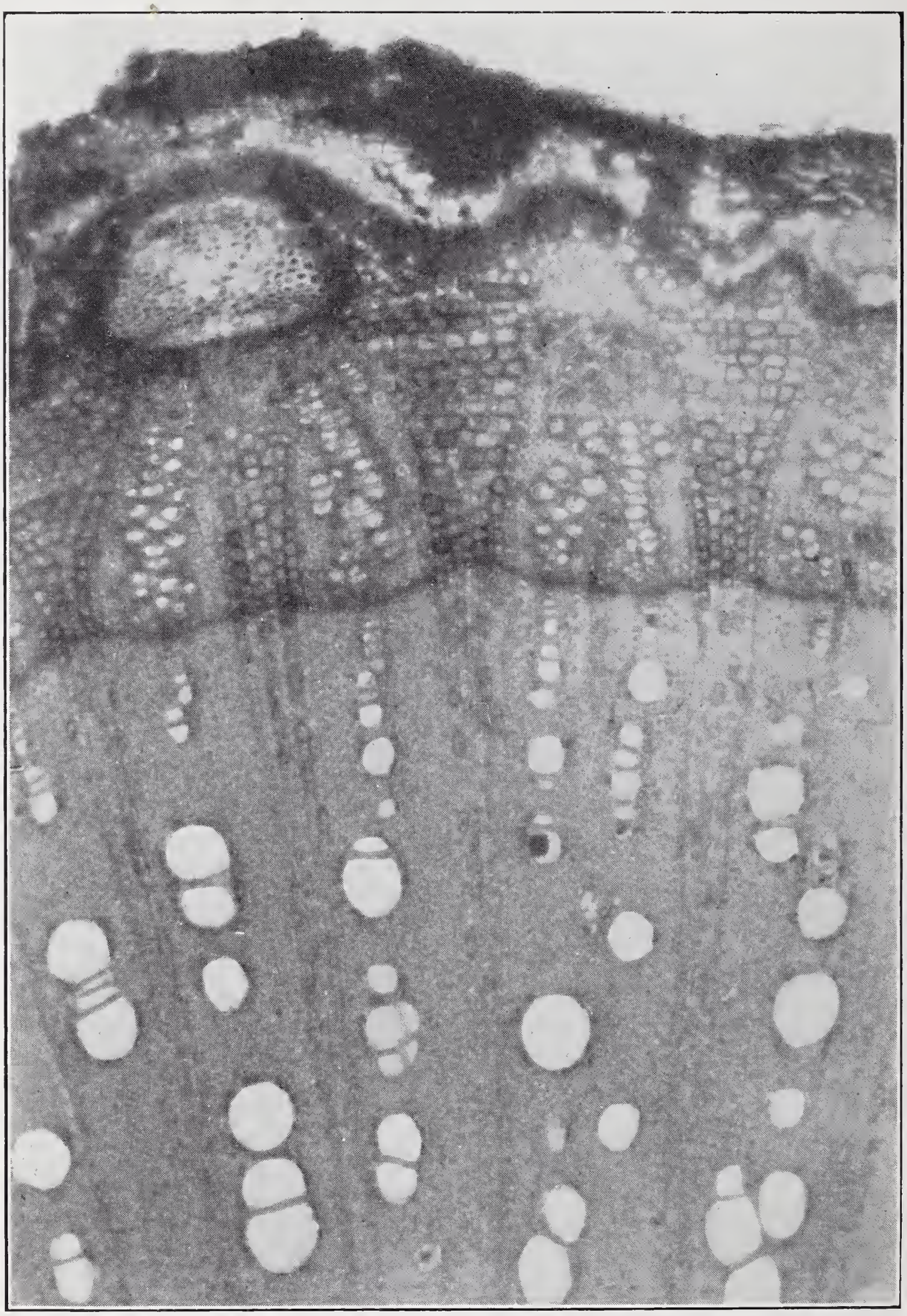

FIG. 7. HYBRID (V. VINIFERA x V. ROTUNDIFOLIA), TRANSVERSE SECTION OF BUNDLES.

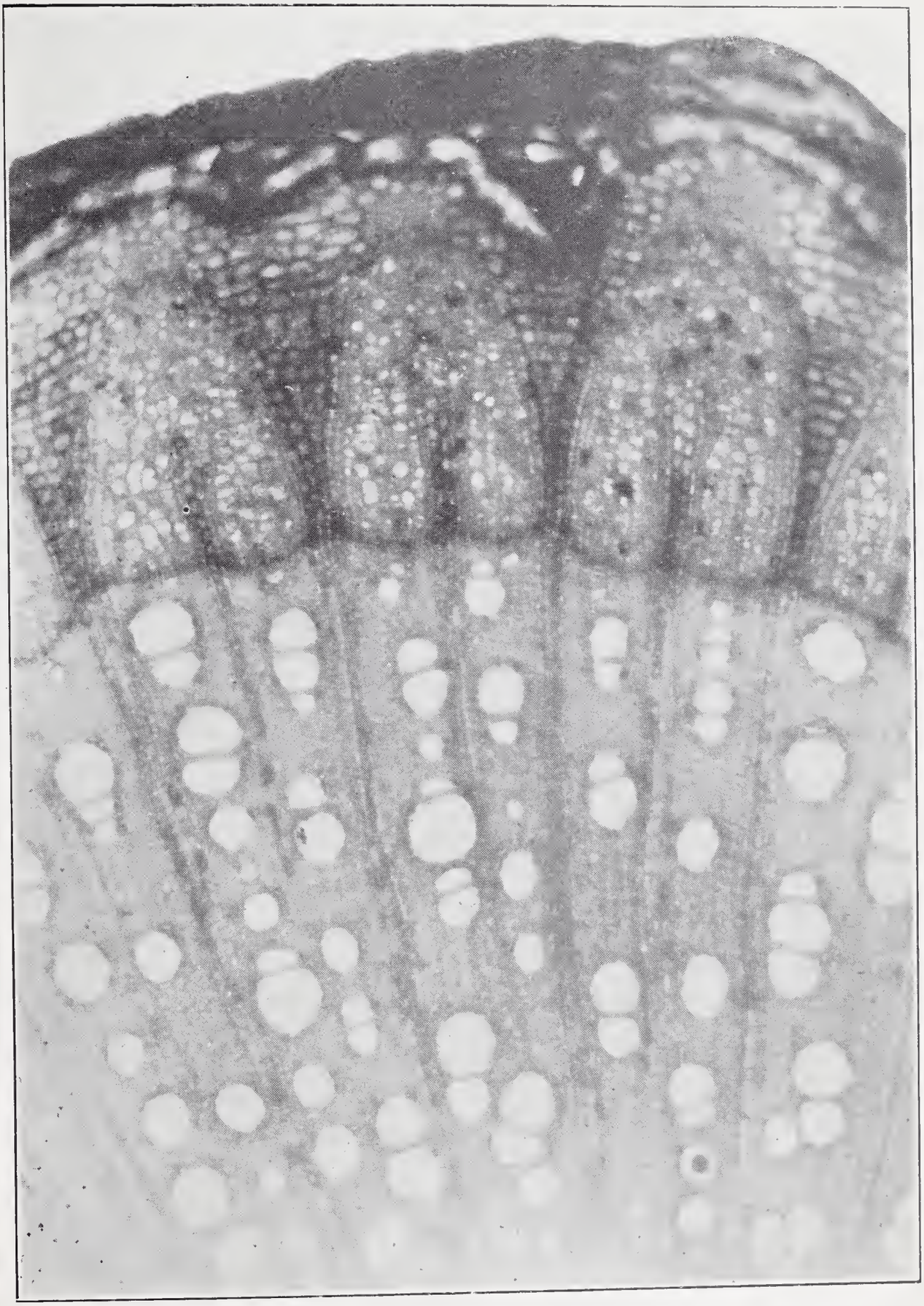

FIG. 8. HYBRID (V. VINIFERA X V. ROTUNDIFOLIA), TRANSVERSE SECTION OF BUNDLES.

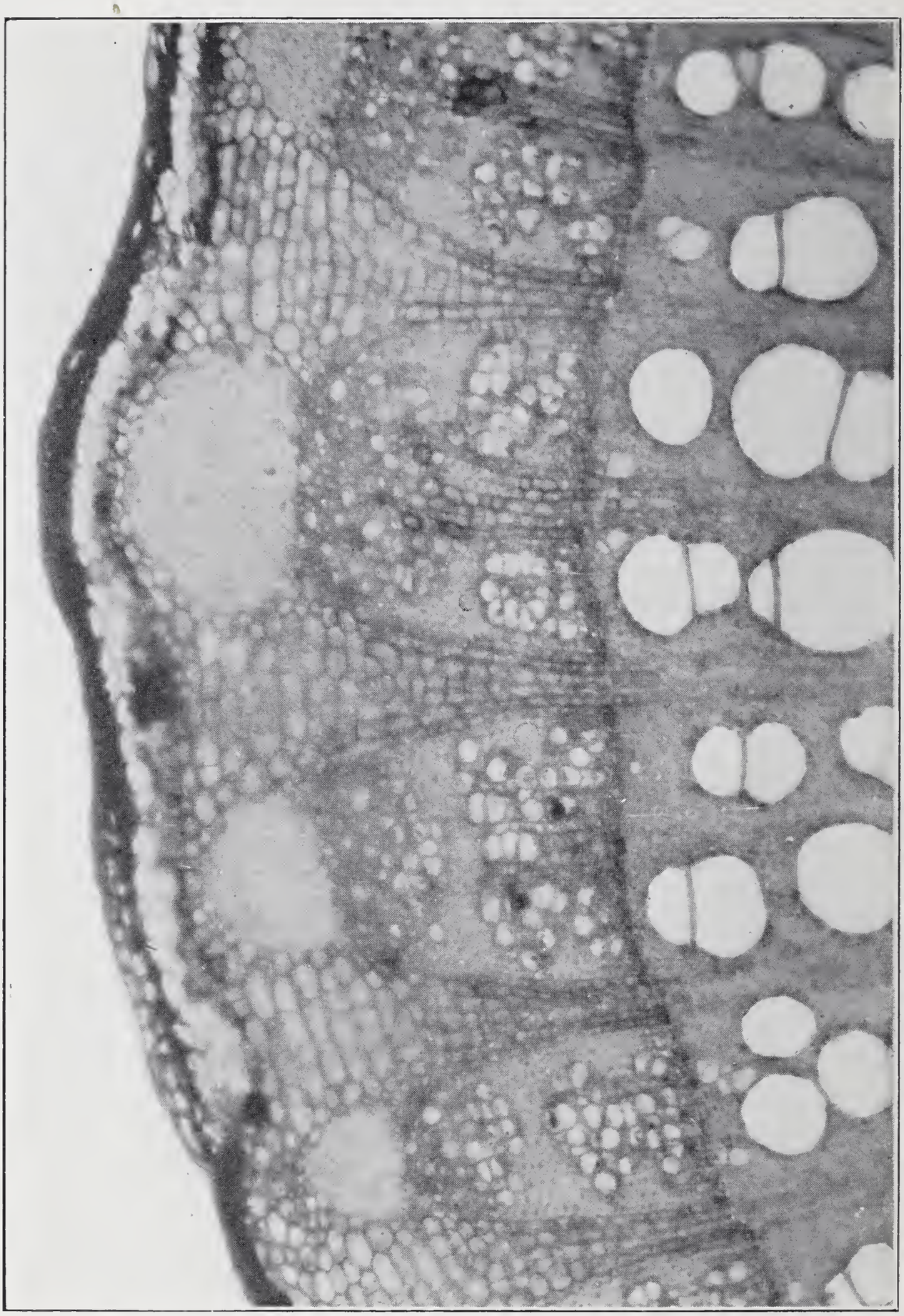

FIG. 9. HYBRID (V. VINIFERA x V. ROTUNDIFOLIA), TRANSVERSE SECTION OF BUNDLES.

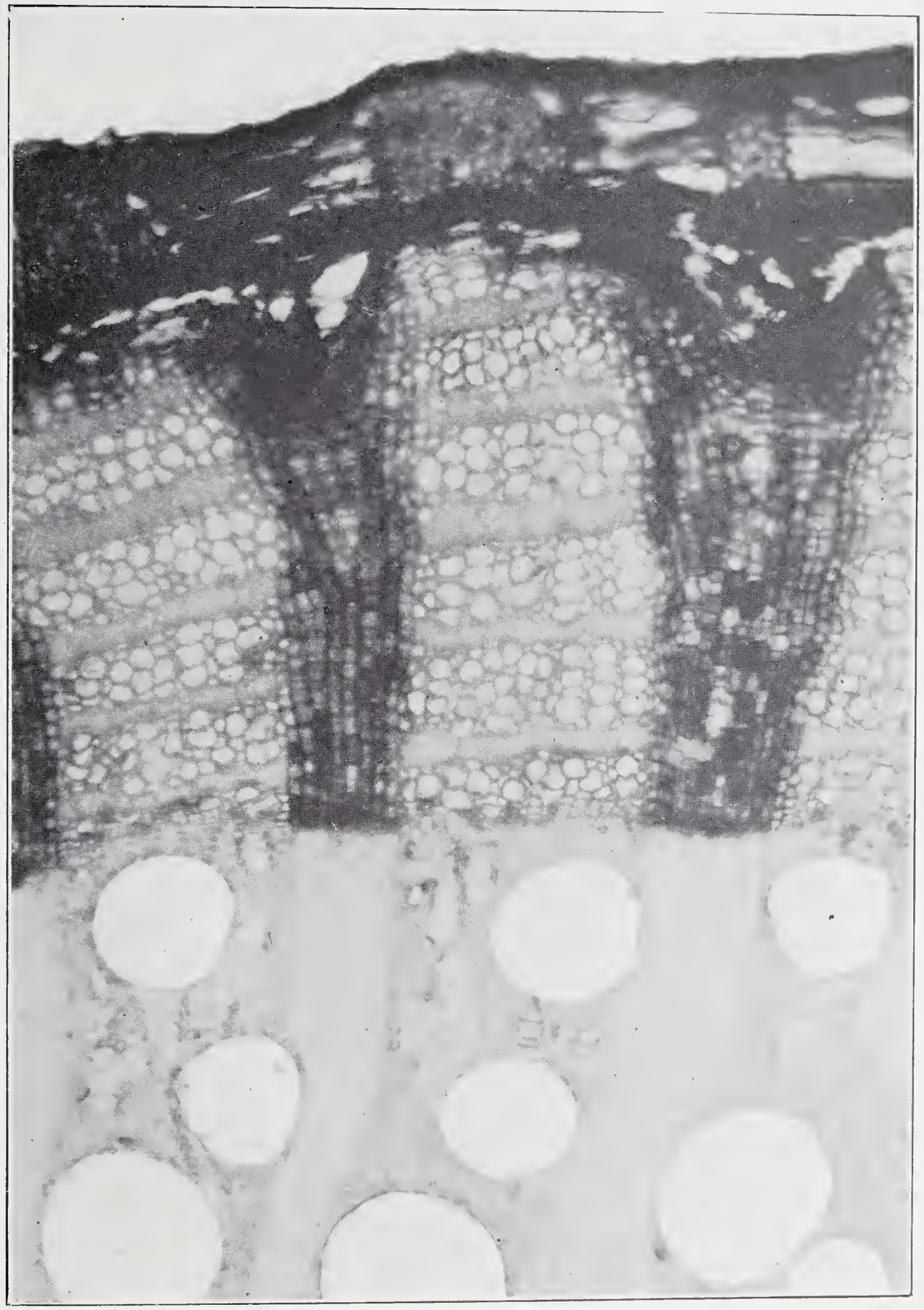

FIG. 10. HYBRID (V. VINIFERA X V. ROTUNDIFOLIA), TRANSVERSE SECTION OF BUNDLES.

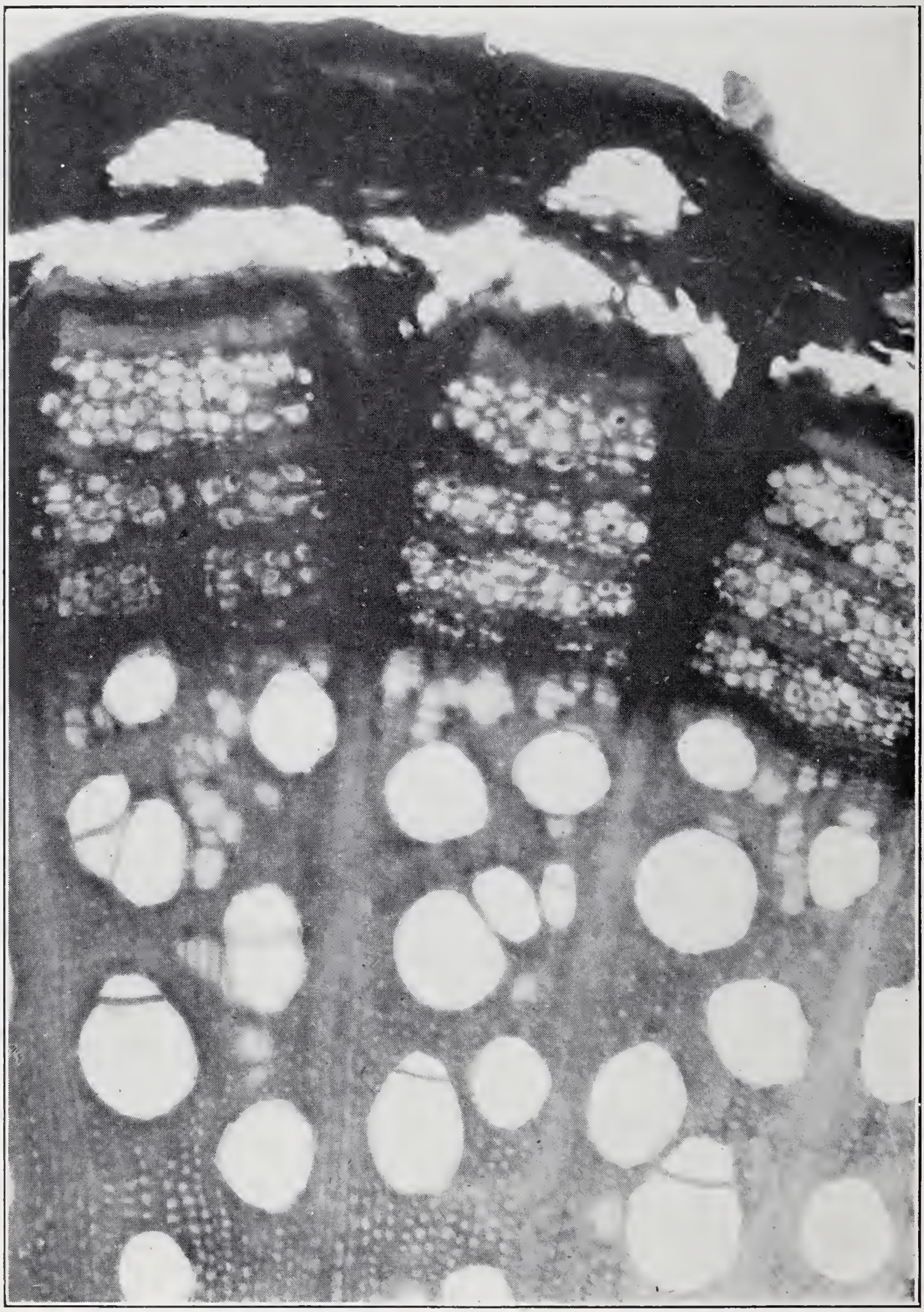

FIG. 45. V. BOURQUINIANA, TRANSVERSE SECTION OF BUNDLES.

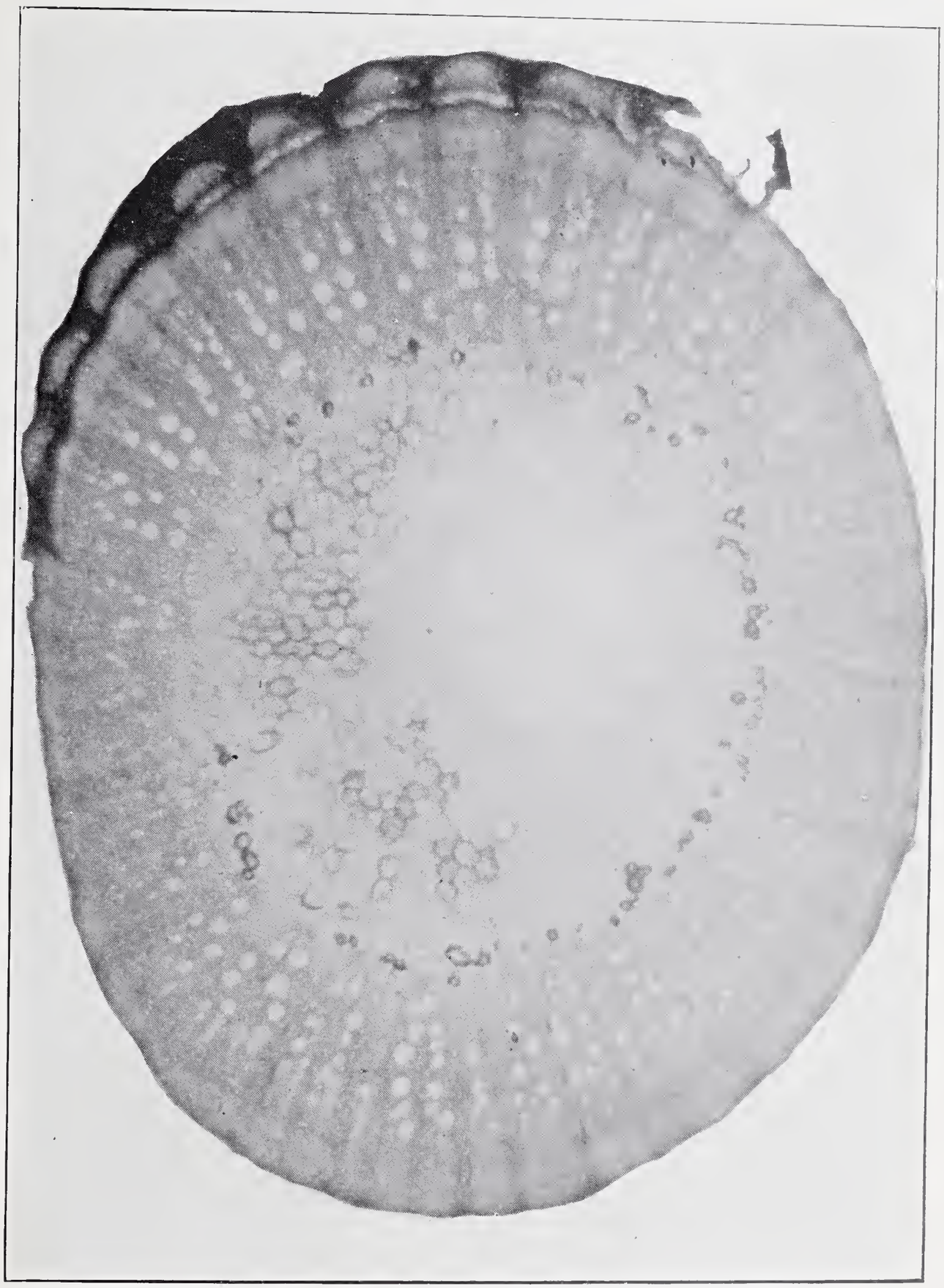

FIG. 46. VARIETY WINCHELL, TRANSVERSE SECTION OF INTERNODE.

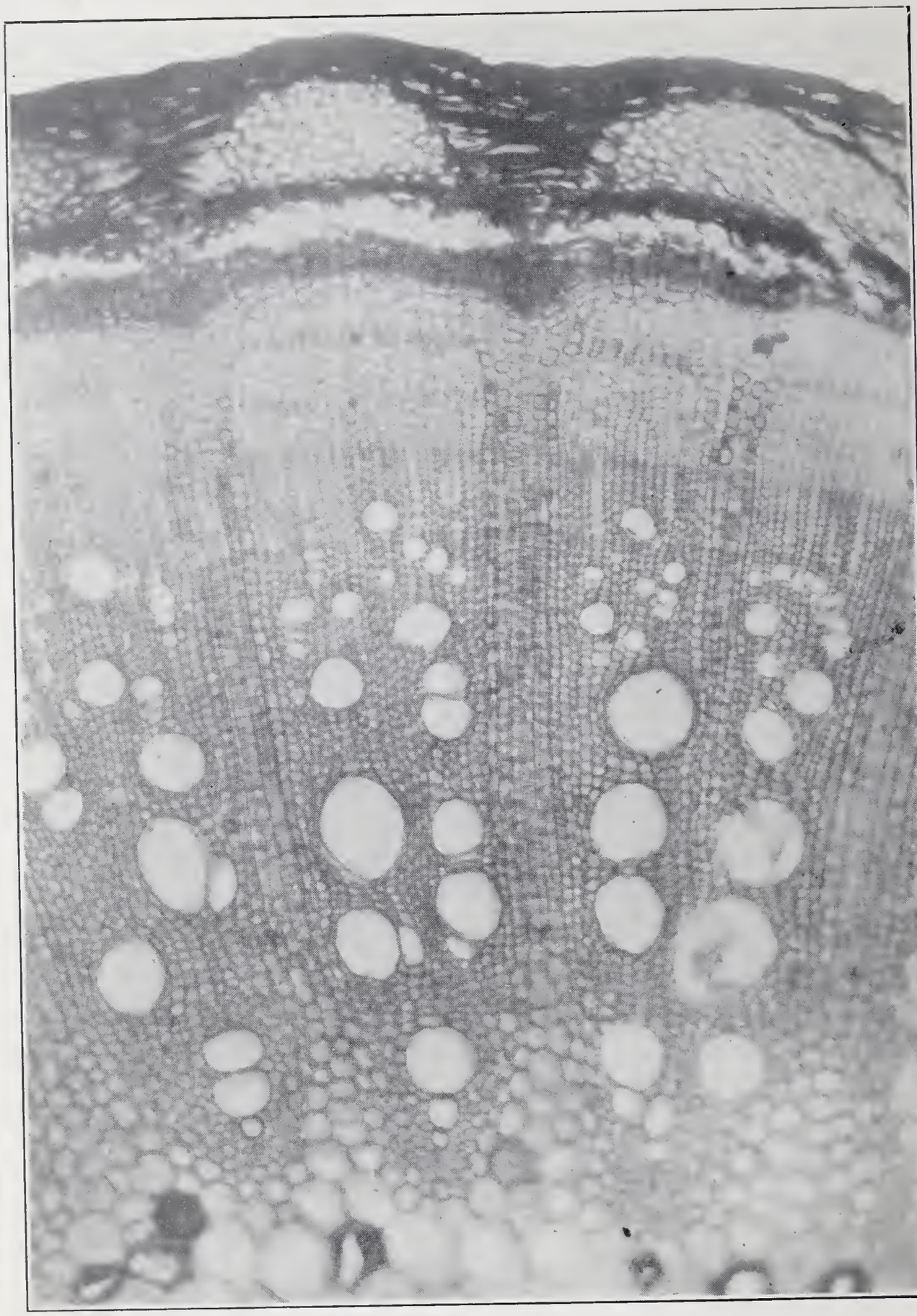

FIG. 47. VARIETY WINCHELL, TRANSVERSE SECTION OF BUNDLES.

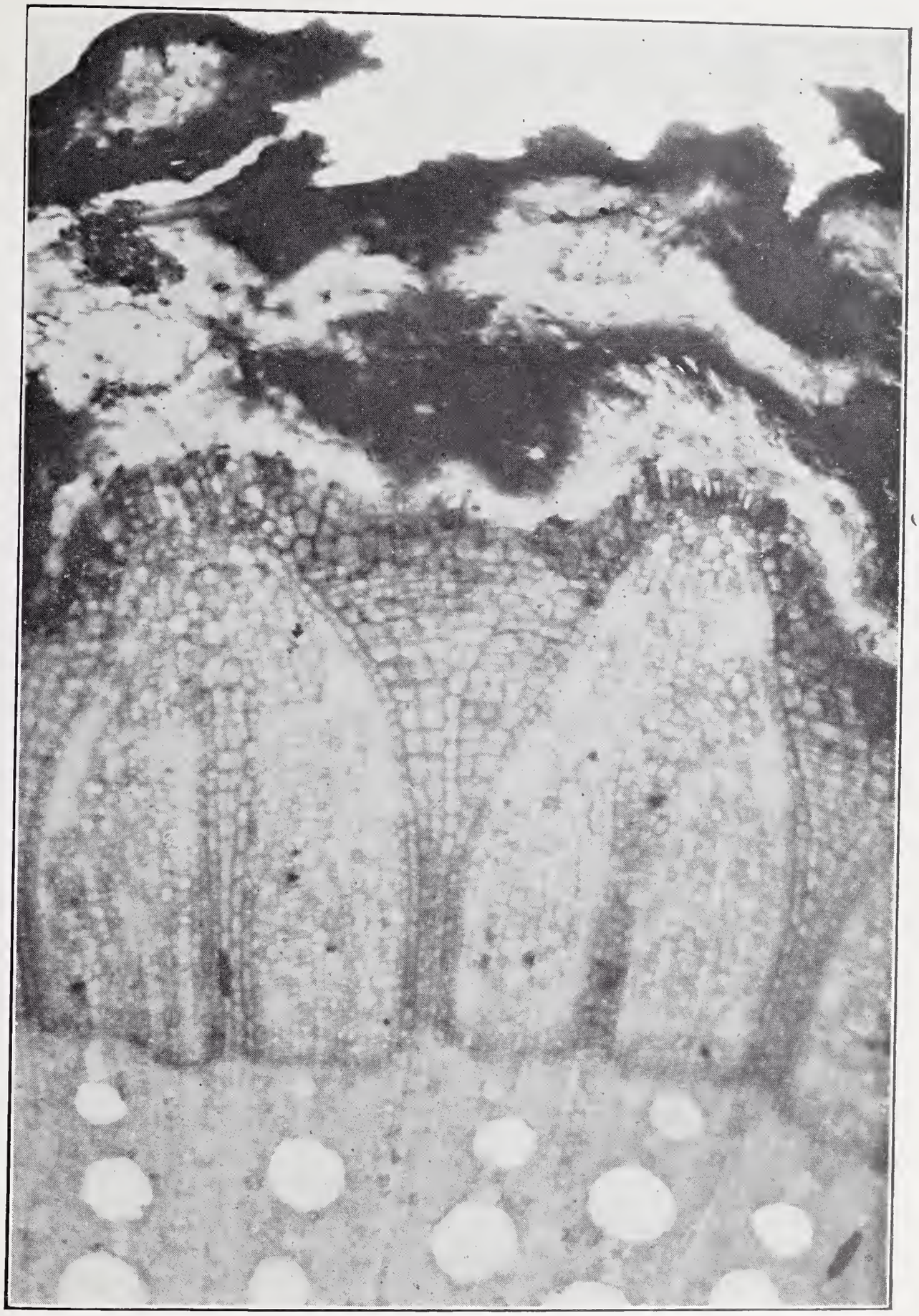

FIG. 76. HYBRID (VAR. WINCHELL x V. ROTUNDIFOLIA), TRANSVERSE SECTION OF BUNDLES.

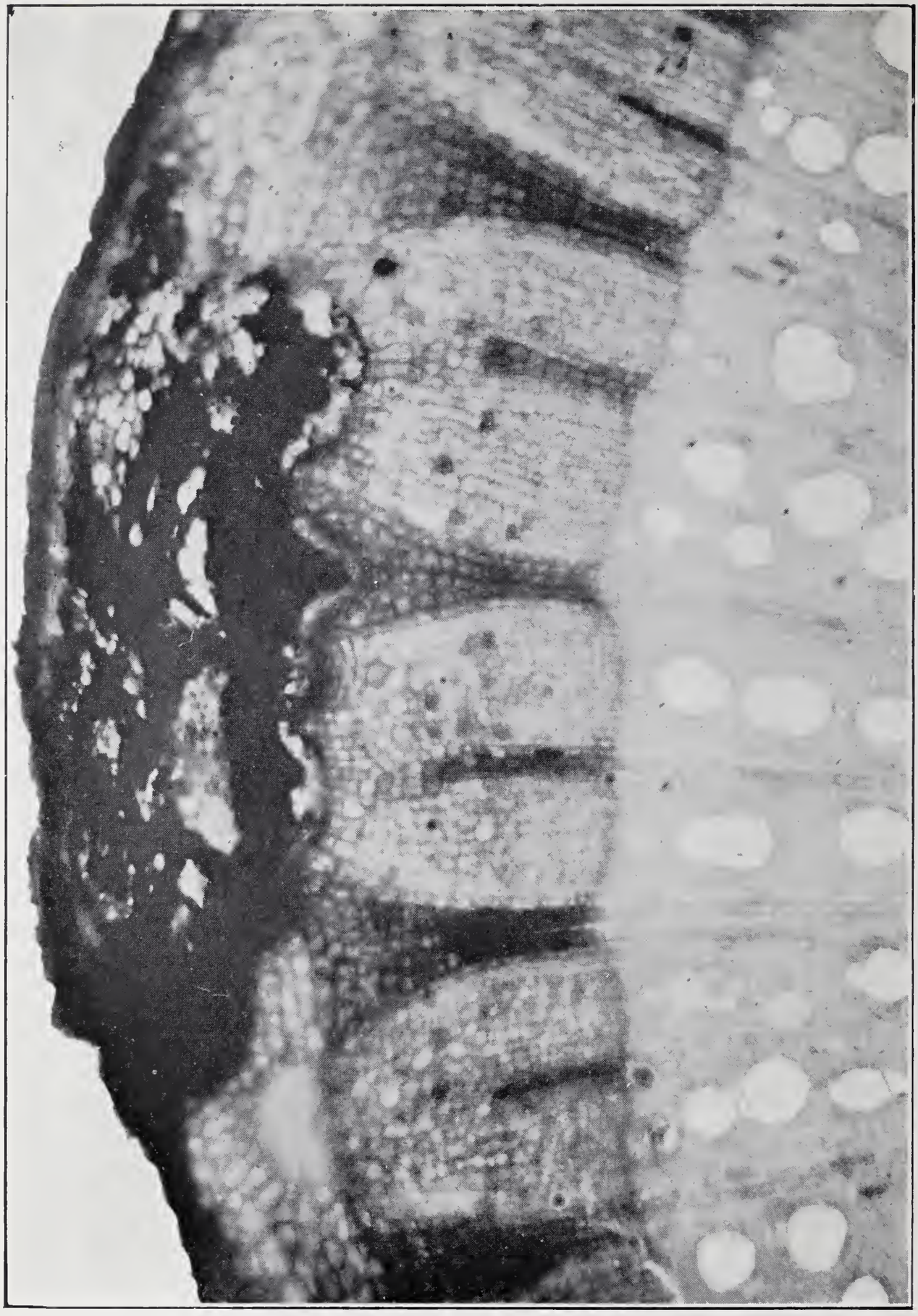

FIG. 77. HYBRID (VAR. WINCHELL X V. ROTUNDIFOLIA), TRANSVERSE SECTION OF BUNDLES.

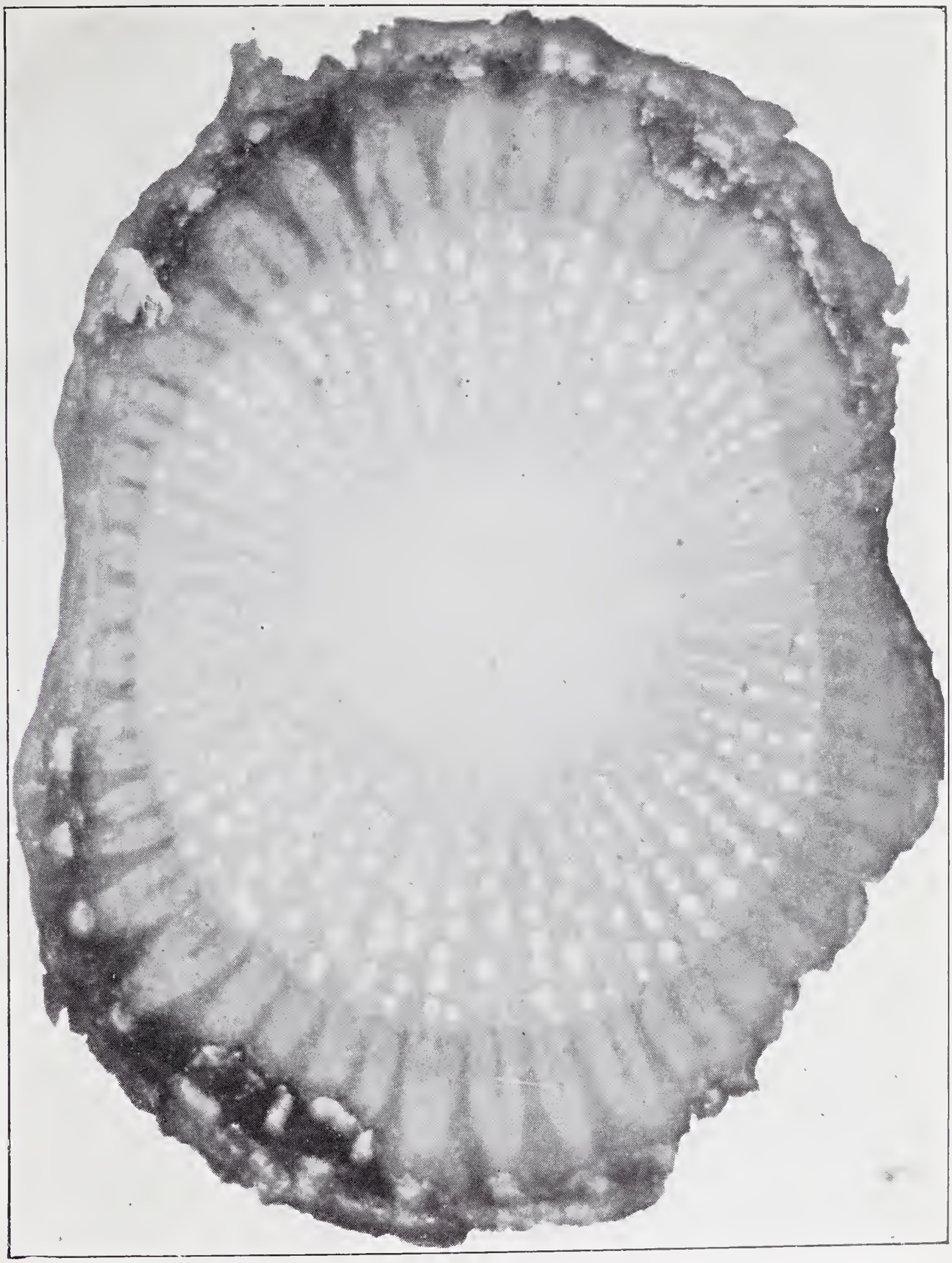

FIG. 78. HYBRID (VAR. WINCHELL X V. ROTUNDIFOLIA), TRANSVERSE SECTION OF INTERNODE

FIGS. 11-44. CAMERA LUCIDA DIAGRAMS OF TRANSVERSE SECTIONS OF BUNDLES. FIG. 11. V. VINIFERA, FIG. 12. V. ROTUNDIFOLIA, FIGS. 13-38. HYBRIDS V. VINIFERA X V. ROTUNDIFOLIA, FIGS. 39-44. HYBRIDS BOURQUINIANA X V. ROTUNDIFOLIA, (*f*) SCLERENCHYMA BUNDLE, (*p*) PHELLOGEN, (*h*) HARD BAST, (*s*) SOFT BAST, (*c*) CAMBIUM, (*r*) RAY, (*v*) VESSEL.


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